A Virtual Reality Simulator to Detect Acrophobia in Work-at-Height Situations

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Abstract

We propose to demonstrate a novel immersive virtual reality simulator aimed at detecting whether potential workers at height are able to climb high up for dangerous operations. Our simulator consists in a dynamic platform that simulates the vibrations of an aerial device during elevation, a real ladder synchronized in position with a virtual one placed on top of a virtual electric pole, a harness that allows users safely climbing the ladder and a head-mounted display (HMD) for visualization. Our demonstration invites users to experience a high fidelity work-at-height situation triggering fear of heights.

Index Terms: Human-centered computing—Human computer interaction (HCI)—Interaction paradigms—Virtual reality; Software and its engineering—Software organization and properties—Virtual worlds software—Virtual worlds training simulations

1 Introduction

Virtual reality (VR) enables to safely reproduce situations that can be dangerous in reality, especially when these situations trigger symptoms such as vertigo, fear, etc. Work at height is one of these situations that can be easily reproduced in VR to train workers [5], preventing them from fatal issues when in real conditions. However, VR-based high-fidelity simulators for such situations are still rare. Through this demonstration we try to fill this gap.

On one hand, from past research, vertigo was hypothesized to originate from a conflict between visual and vestibular information [2]. When high up, without any close and stable visual references, subjects must rely on their proprioceptive and vestibular information to stay stable, which may generate the sensation of vertigo [3].

On the other hand, past research has shown VR to be efficient in reproducing psychophysiological symptoms of a real exposure to height [6, 10] or in treating acrophobia [4, 7]. To ensure fidelity in the simulation, an important parameter to consider is presence. However, several studies contradict each other on the relation between presence and anxiety [1, 8]. Nonetheless, the main parameter for anxiety to develop seems to be the perceived realism of the virtual environment.

Last, in work-at-height situations, vertical navigation is needed, which was mostly addressed in past work by tricking subjects with techniques such as marching in place [9, 11].

Considering past work, we built a simulator trying to reproduce real work-at-height situations, by tricking users as little as possible and triggering psychophysiological symptoms of a real exposure to height. We investigate the parameters influencing the fear of heights in a virtual environment and allowing high fidelity in the simulation. Our simulator has not been designed to serve as a therapy tool, but to provide high fidelity simulations that can be used by companies to detect whether potential future workers develop acrophobia in real work-at-height operations before exposure to real conditions.

2 Demonstration

2.1 Use Case

The simulator we propose to demonstrate was built upon requirements from a company working on the maintenance of power lines. The use case addressed here is based on typical operations performed by the company's employees: go to the top of an electric pole thanks to an aerial device, get harnessed to the pole to evolve safely, climb on a ladder placed on top of the pole, then perform maintenance on the power lines.

2.2 Hardware

We designed our simulator to be transportable so that it can be used anywhere needed. Therefore we opted for devices that are easy to carry and set up. We use an HTC Vive head-mounted display (HMD) for visualization, coupled with a VR-Ready Windows 10 PC. An audio headset provides phonic immersion. Four Vive trackers are placed on the user's tibia and hands. The trackers are mainly used to provide users with visual feedback of their hands and feet positions, as HMDs shield users from reality.

We integrate a home-made dynamic platform to reproduce the vibrations of a virtual aerial device during its motion. This platform consists in four electric actuators (maximal displacement: 8 cm) that can be controlled independently from the others. They allow motion around the pitch and roll axes and along the vertical axis, as well as vibrations at frequencies up to 3 kHz. The platform is synchronized in position with the virtual aerial device.

Since past research showed an enhancement in the simulation when including real objects [5], a real ladder synchronized in position with its virtual representation in the virtual environment is included in the setup so that users can climb it for real during the simulation. We then ensure a perfect match between the real and the virtual environments in terms of body sensations (e.g., sensation of gravity, fear of falling) and physical efforts. Users are equipped with a harness for their safety. The ladder can be easily attached and removed from a pole that can be part of a lightweight structure.

The whole hardware setup is depicted in Fig. 1. It takes about 45 minutes to be set up and calibrated. It has already been mounted and demounted in several places such as entry halls of buildings.

2.3 Virtual Environment

The virtual environment includes an aerial device with a moving platform and a virtual ladder placed on top of a common electric pole (11.6 meters above the ground). The surrounding environment is composed of buildings, rocks, hills and trees that are above 10 meters in distance so that no static spatial reference can be provided to users and so easily trigger vertigo [2]. Moving clouds have been added to the sky to strengthen the effect of loss of static spatial

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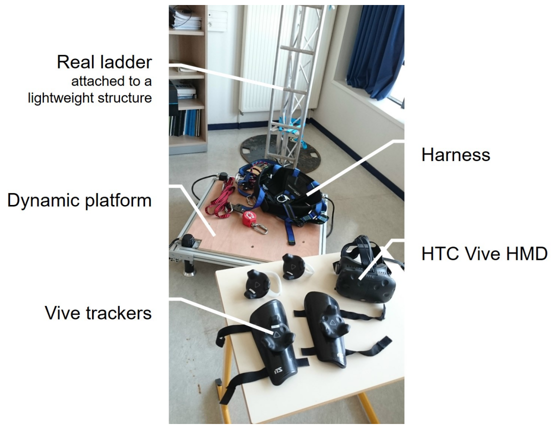

Figure 1: The whole simulator setup.

references. Dynamism is included in the scene thanks to moving cars and 3D sounds emitted by the environment.

As the HMD shields users from reality, we included the possibility to see a virtual representation of users' hands and feet to serve as a visual guide. We chose as a first implementation to represent only hands and feet to simplify motion tracking computation. These parts are just tracked in position thanks to the Vive trackers and not kinematically animated.

2.4 Proposed Experience

We propose in our demonstration to perform the task described in the use case above. Because such simulator is not common, our demonstration invites to a unique user experience, detailed as follows (see Fig. 2):

1. stand on the platform of a virtual aerial device and virtually rise at 11 meters above the ground with multisensory feedback (users can experience vibrations of the virtual aerial device when rising up, sway when high up due to the wind). Users are already equipped with the harness as in real conditions;

2. step physically onto the real ladder and climb one or two steps while being totally immersed. As the dynamic platform is around 30 cm above the ground, there is a physical gap between the platform and the ladder, strenghtening presence;

3. try to catch with both hands a virtual kite stuck in the lines and placed behind users, while being attached to the ladder with the harness (in a real operation, workers would not necessarily catch a kite, but we chose this simple task as it may already not be so easy for acrophobic users, since they need to remove *both* hands off the ladder and so be confident in the harness, thus providing thrill during the experience).

The whole demonstration can last less than five minutes, depending on the users' susceptibility to acrophobia. Anytime, users are able to stop the demonstration if needed (e.g., sickness felt, vertigo).

3 Extensions

We expect our simulator to be deployed in companies dealing with work at height as an additional tool to detect acrophobic persons and thus hire only non-acrophobic workers. Though our simulator meets the first industrial requirements, it is still in development and further functionnalities need to be added. Especially we could integrate other sensory cues such as air motion to simulate gusts of wind while at height. As the tasks addressed here are usually performed with live power lines, we could add a haptic feedback when a user touches a virtual power line.

Figure 2: The work-at-height simulator in operation.

User studies are also planned with both experienced and inexperienced workers to compare with reality.

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